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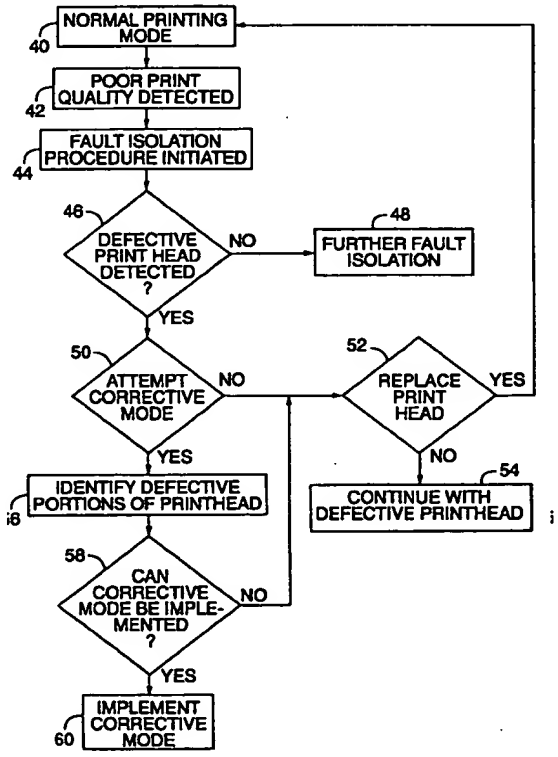
(54) System and method for printing with a portion of an ink-jet print head

(57) A system and method for printing with a portion of an ink-jet print head 26 allows for defect-free printing even with a print head 26 containing defective ink-jets 28. Where some ink-jets 28 on a print head 26 are defective, the print head is controlled to print, albeit at a reduced speed, using only properly functioning ink-jets. For example, if the top half of a print head 26 contains one or more defective ink-jets 28, the top half of the print head could be disabled. Then using the defect-free bottom half of the print head, the printer can continue to print with high print quality. In this example, the printer would make two swaths with the bottom half of the print head to print what would normally be printed in a single swath of a fully functional print head. A system for detecting and locating defective ink-jets is provided.

FIG. 5



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a system and method for controlling a print head in an ink-jet printer and, more particularly, to a system and method for controlling the print head in a manner that allows the printer to maintain print quality while printing with only a portion of the print head. For example, if a portion of the print head fails, print quality is maintained by controlling the print head in a manner that does not use the defective portion of the print head. The invention also relates to a system for identifying which, if any, portion of a print head is defective.

2. Description of Related Art

Ink-jet printers are reliable and efficient printing devices. Typically, an ink-jet printer utilizes a print head mounted on a carriage which moves back and forth over a print medium, such as paper. The print head commonly has one or more ink jets which can be selectively activated to eject a small quantity of ink onto the print medium. A control system selectively activates the appropriate ink jets as the print head moves over the appropriate locations on the print medium to form desired images and characters.

The print head typically includes an array of several ink jets arranged in columns or rows. This allows the print head to print a "swath" as it is moved across the print medium. For example, in a printer having a one-half inch print head, the ink-jets would typically be arranged in a vertical (as defined by the direction of print medium travel) array one-half inch high. The print head is moved horizontally across the surface of the print medium and the control system selectively activates the individual ink-jets to print a one-half inch swath. The print medium is then advanced vertically one-half inch and the print head is moved back across the print medium to print another one-half inch swath. This process is repeated to print an entire sheet.

However, at some point, one or more ink-jets on a print head will fail. Failure may result from defects in the print head, cracks forming in the passivation layer, clogging of the ink-jet, mechanical wear or other reasons. Such failures may cause the ink-jet to miss fire, to misdirect the ejected ink or to fail to eject any ink. In any case, failure of one or more ink-jets on a print head can decrease the print quality of the print head.

Unacceptable print quality resulting from failed ink-jets has previously been corrected by replacing the entire print head. Thus, if a new print head was unavailable or if a user was unable to replace a partially failed print head, the user would either have to tolerate low print quality or delay printing until a new print head could be installed. Each of these alternatives is often unacceptable to a user who requires high print quality and cannot afford to delay until a replacement print head can be located and installed.

SUMMARY OF THE INVENTION

A system in accordance with a preferred embodiment of the present invention reduces the inconvenience associated with many defective print heads by controlling the printer in a manner that produces high print quality using less than all of the ink-jets on a print head. In particular, where some ink-jets on a print head are defective, the print head is controlled to print, albeit at a reduced speed, using only properly functioning ink-jets. For example, if the top half of a print head contains one or more defective ink-jets, the top half of the print head could be disabled. Then using the defect-free bottom half of the print head, the printer can continue to print with high print quality. In this example, the printer would make two swaths with the bottom half of the print head to print what would normally be printed in a single swath of a fully functional print head. Thus, the print speed would be reduced by approximately half.

In one aspect of the present invention, a system for detecting and locating defective ink-jets is provided. In particular, a print head having potentially defective ink-jets can be controlled to print a test pattern. Defects in the printed test pattern can be detected to indicate the existence of defective ink-jets. Further, the test pattern may be such that the location of defects in the test pattern allows for the location of the defective ink-jet to be determined. For example, a first portion of the test pattern may be printed using only a top portion of the print head and a second portion of the test pattern may be printed using only a bottom portion of the test pattern. In this example, defects appearing in the first portion of the test pattern would not only indicate that the print head contained defective ink-jets, but also that the top half of the print head contained defective ink-jets. Depending on the number of discrete portions of the print head used to print portions of the test pattern and upon the nature of the test pattern, this system may be used to locate defective ink-jets with even greater accuracy.

Other objects and aspects of the invention will become apparent to those skilled in the art from the detailed description of the invention which is presented by way of example and not as a limitation of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a block diagram of a printing system into which a preferred embodiment of the present invention is incorporated.

Figure 2 shows a schematic representation of a print head of the printing system of Figure 1.

Figure 3 illustrates the print head of Figure 2 oper-

ating in the normal print mode.

Figure 4 illustrates the print head of Figure 2 operating in the corrective mode.

Figure 5 is a flow chart illustrating a preferred method of implementing an embodiment of the present invention in the printing system of Figure 1.

Figure 6 is a flow chart illustrating a preferred method of identifying the location of defective ink-jets.

Figure 7 illustrates an example of how a print head can be defined into print zones.

Figure 8 is an exemplary test pattern for use in the method of Figure 6.

Figure 9 is an alternative example of a test pattern for use in the method of Figure 6.

DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

A block diagram of an exemplary printing system into which a preferred embodiment of the present invention can be implemented is indicated in Figure 1 by reference numeral 10. The exemplary printing system includes a host computer 12 coupled to a printer 14. The printer 14 includes an interface buffer 16 which receives data and instructions from the host computer 12. The data and instructions from the host computer are then processed by a microprocessor 18 in accordance with a program stored in a program memory 20. Under the control of the microprocessor 18, data to be printed is stored in a bit mapped memory 22. The microprocessor also controls a print head controller 24 which retrieves data from the bit mapped memory and coordinates firing of the individual ink-jets 28 during the movement of the print head 26 to print the retrieved data. In addition, the microprocessor 18 provides information to a motor control unit 30. The motor control unit 30 provides control signals to one or more motors 32 which, in turn, control movement of the print head 26 across the paper and advance the paper through the printer 14 after each swath of the print head 26. The hardware illustrated in Figure 1 may be that found in conventional ink-jet printing systems.

A schematic representation of the print head 26 is illustrated in Figure 2. The print head 26 has an array of ink jets 28 from which ink is expelled during printing. In the illustrated print head, the array of ink jets 28 is made of ink-jets arranged in two columns 36a and 36b with each column having one hundred fifty-two ink jets 28 spaced one three hundredth of an inch apart. The ink jets in column 36a are vertically offset by one six hundredth of an inch from those in column 36b. In the illustrated configuration, the print head 26 can print a one half inch swath at a resolution of 600 dots per inch (dpi). Of course, other sizes and configurations of print heads could also be used to implement the present invention.

In the preferred embodiment of the present invention, the printing system 10 is operable in at least two different modes: a normal mode in which all ink-jets are available for printing and a corrective mode in which some ink-jets are disabled and are not available for printing. In the normal mode, illustrated in Figure 3, the print head 26 is moved horizontally over a sheet of paper 38 or other print medium, and the print head controller 24 selectively activates appropriate ink-jets 28 at appropriate times to print the data stored in bit mapped memory 22. For purposes of illustration only, the data stored in the bit mapped memory 22 contains the characters "ABC" one-half inch high. Because the illustrated print head 26 is a one-half inch print head, this data can be printed in a single swath of the print head 26, as illustrated in Figure 3.

In the corrective mode, illustrated in Figure 4, less than all of the ink-jets 28 on the print head are available for printing. For example, the ink-jets on the bottom half of the print head may be disabled. In this example, the print head controller 24 could still print the data, but would require at least two swaths of the print head. As illustrated in Figure 4, the print head controller could print the top half of the illustrated data on a first swath, advance the print medium 38 one half the normal distance, and print the bottom half of the data on a second swath.

Figure 5 is a flow chart illustrating a preferred process for changing between the normal printing mode and the corrective printing mode. In the normal print mode, step 40, poor print quality is detected, for example by a user observing defects in printed images, step 42, and a fault isolation procedure is initiated, step 44. The fault isolation procedure is preferably an algorithm which helps to identify the cause of poor print quality. For example, the fault isolation procedure may display queries and solicit responses to assist in diagnosing the cause of poor print quality. The fault isolation procedure may also perform internal diagnostic tests to troubleshoot problems with various components of the printing system. Preferably, the fault isolation procedure is implemented as a set of computer software or firmware instructions executed by the host computer 12, the microprocessor 18, or both. Many printers include some type of fault isolation procedure or diagnostic routine for detecting various printer problems. Those skilled in the art could either modify existing fault isolation procedures or could create new fault isolation procedures to implement the current system.

In accordance with the illustrated embodiment, part of the fault isolation procedure would determine whether the poor print quality is attributable to a defective print head, step 46. If the poor print quality is not attributable to the print head, the fault isolation procedure may continue in an effort to identify potential causes, step 48. Aside from detecting a faulty print head, the exact operation and implementation of the fault isolation procedure is not critical to the current system.

Once the print head has been identified as a cause of the poor print quality, the user is given the option of

attempting to implement the corrective mode, step 50. If the user opts not to attempt to implement the corrective mode, the user may either replace the print head, step 52, and resume normal printing or may simply continue to print with the defective print head, step 54.

If the user opts to implement the corrective mode, further diagnostics are performed in an effort to locate which portion or portions of the print head are defective, step 56. If the defective portion or portions of the print head cannot be identified or if the remaining portions are not sufficient to allow printing, step 58, the corrective mode cannot be implemented and the user can either replace the print head, step 52, or continue printing with the defective print head, step 54. Otherwise, the defective portion or portions of the print head are disabled and the corrective mode is implemented, step 60.

Those skilled in the art will recognize several methods can be used to identify which portions of a print head are defective, step 56. Figure 6 is a flow chart illustrating one preferred method. The process of Figure 6 is initiated when a user opts to attempt the corrective mode, step 64. In the illustrated method, the printing system defines various print zones on the print head, step 66. An example of one possible definition of the print zones is illustrated in Figure 7. In Figure 7, the print head 26 is divided vertically into quarters with each quarter being a fault isolation zone, 62a-d. Any two adjacent fault isolation zones form a print zone, 63a-c. Thus, there are three print zones, each of which is approximately one-half the size of the print head. Of course, a different number of print zones or different sizes and arrangements of print zones could also be used. However, in the illustrated printing system, the use of three print zones is believed to provide a good compromise between accuracy of defect location identification and simplicity.

The print head controller 24 then controls the print head to print a test pattern, step 68. The test pattern may be any suitable pattern that allows for the identification of defective print zones. Exemplary test patterns are illustrated in Figures 8 and 9 as reference numerals 64a and 64b, respectively. As indicated in Figures 8 and 9, in each of the illustrated test patterns, a discrete portion of the pattern is printed with a single print zone. That pattern also uses each ink-jet within the print zone to print the test pattern. As a result, any defective ink-jets within a particular print zone will adversely affect the print quality of the portion of the pattern printed with that print zone.

After the test pattern is printed, the illustrated system requests and obtains user input as to which, if any, portions of the test pattern contain defects, step 70. For example, if a portion of the test pattern contains broken or uneven lines, or extraneous spots or markings, it may indicate the presence of one or more defective ink-jets within the print zone used to print that portion. In some embodiments, it may be desirable to display defect-free test patterns or examples of defective test patterns on the computer screen so that the user will have some basis for evaluating the printed test pattern. Based upon the user input, print zones which produce acceptable print quality are identified, step 72. Using the test pattern of Figure 8 as an example, if a user indicates that swatch 1 of the test pattern is of unacceptable quality and the rest of the pattern is of acceptable quality, the system can conclude that fault isolaton zone 62a contains one or more defective ink-jets, and that fault isolation zones 62b-d do not. Thus, print zones 63b or 63c can be selected for use in corrective mode.

The results of the process illustrated in Figure 7, are used to determine whether the corrective mode can be entered, step 58 of Figure 6. This determination is based both on the identified defects in the print head and on the constraints of the particular corrective scheme which is allowed in a given system. For example, in the illustrated example, the system is designed such that in the corrective mode, any two adjacent defect-free fault isolation zones are used and the remaining fault isolation zones are deactivated. Thus, if the system determines that fault isolation zones 62a and 62c contain defective ink-jets, the corrective mode is not possible because there are not two adjacent fault isolation zones without defective ink-jets. Likewise, if all four fault isolation zones are found to contain defective ink-jets the corrective mode is not feasible.

It should be appreciated that the illustrated configuration and implementation is one of design choice. It is possible to define more or fewer than three print zones or four fault isolation zones. It is also possible to use nonadjacent fault isolation zones to define a print zone or to use more or fewer than two fault isolation zones to define a print zone. At one extreme, the test pattern could be selected such that each individual ink jet can be independently identified and evaluated. Alternatively, the print head could be divided to define only two print zones. It is also possible to define the print zones by columns or any other suitable criteria. Likewise the particular implementation of the corrective mode is also a matter of design choice. For example, the corrective mode could be implemented using non-contiguous print zones or using more or fewer than two print zones. The particular system described is believed to represent a good compromise between the complexity which would be required to identify faulty ink-jets with more accuracy and to use more possible configurations in the corrective mode, and the simplicity needed to allow a user to easily and accurately respond to the system queries and to allow simple and reliable implementation. Nonetheless, those skilled in the art will recognize that other configurations may also be used, and depending on the particular circumstances, may be desirable.

The implementation of the corrective mode may be done in a variety a ways. In the illustrated system, the print head controller 24 is provided with a map, stored in non-volatile memory, of available ink-jets. The print head controller uses this map to determine which ink-

jets are available for printing and then controls the movement of the print head and activation of the available ink-jets to print the desired characters and images. In this type of print head controller, an ink-jet may be disabled by removing it from the map of available ink-jets. Thus, the corrective mode can be implemented by removing those ink-jets within those print zones that are to be disabled from the map of available ink-jets. Of course, other methods of implementation may also be available and may be more suitable for other types of print head controllers.

As described, the current system may be implemented into an existing printing system by altering the software, firmware and algorithms used to control the existing printing system. Those skilled in the art will readily recognize, based on this description, the manner in which such existing systems may be altered and would be able to modify or prepare appropriate software, firmware or algorithms. Alternatively, those skilled in the art would also be able, based upon this disclosure, to implement the current system into a new printing system.

This detailed description is set forth only for purposes of illustrating examples of the present invention and should not be considered to limit the scope thereof in any way. Clearly, numerous additions, substitutions, and other modifications can be made to the invention without departing from the scope of the invention which is defined in the appended claims and equivalents thereof.

Claims

1. A method of printing with an ink-jet printer 14 having a print head 26 with a plurality of ink-jets 28, at least one of which is defective, comprising the steps of:

   defining a plurality of print zones 63 on the print head 26, each print zone 63 containing at least one ink-jet 28;
   determining whether a print zone 63 contains a defective ink-jet 28;
   disabling a print zone 63 that contains a defective ink-jet 28; and
   printing.

2. The method of claim 1 wherein the determining step further comprises the steps of:

   printing a test pattern, the test pattern having a plurality of different regions, each region associated with one or more print zones;
   requesting a user to identify regions of the test pattern which show unacceptable print quality; and
   identifying, based on the user identification, print zones 63 associated with regions having unacceptable print quality.

3. The method of claim 1 in which the print head 26 is a linear array of two columns 36 of ink jets 28 divided into three print zones 63.

4. The method of claim 3 in which the print head controller 24 is provided with a map of ink-jets 28 available for printing and in which the disabling step further comprises the steps of:

   altering the map to indicate that ink-jets within the print zones to be disabled are not available for printing.

5. A method of printing using an ink-jet print head 26 having a plurality of print zones 63 each containing at least one ink-jet, the method comprising the steps of:

   for each of said plurality of print zones 63;

   firing each ink-jet 28 within the print zone 63;
   determining whether any ink-jet 28 within the print zone 63 misfired; and
   in response to a positive determination disabling all of the ink-jets 28 within the print zone 63.

6. The method of claim 5 further comprising the step of printing with the non-disabled print zones 63.

7. A system for printing using a partially defective print head 26, the print head having a plurality of ink-jets 28 for selectively ejecting ink onto a print medium 38, the system comprising:

   a memory 22 for storing data to be printed;
   a mechanism 32 for moving the print head 26 over the print medium;
   a map stored in memory indicating which of the plurality of ink-jets is available for printing;
   print head controller 24 for selectively activating each of the plurality of ink-jets indicated in the map as available for printing;
   means for identifying a portion of the print head containing one or more defective ink-jets; and
   means for altering the map to remove those ink-jets contained within the identified portion of the print head.

8. The system of claim 7 in which the means for identifying a portion of the print head 26 containing defective ink-jets comprises:

   means for defining a plurality of print zones 63 on the print head;

means for printing a test pattern, the test pattern having a portion printed by each print zone; and

means for determining which portions of the test pattern have unacceptable print quality.

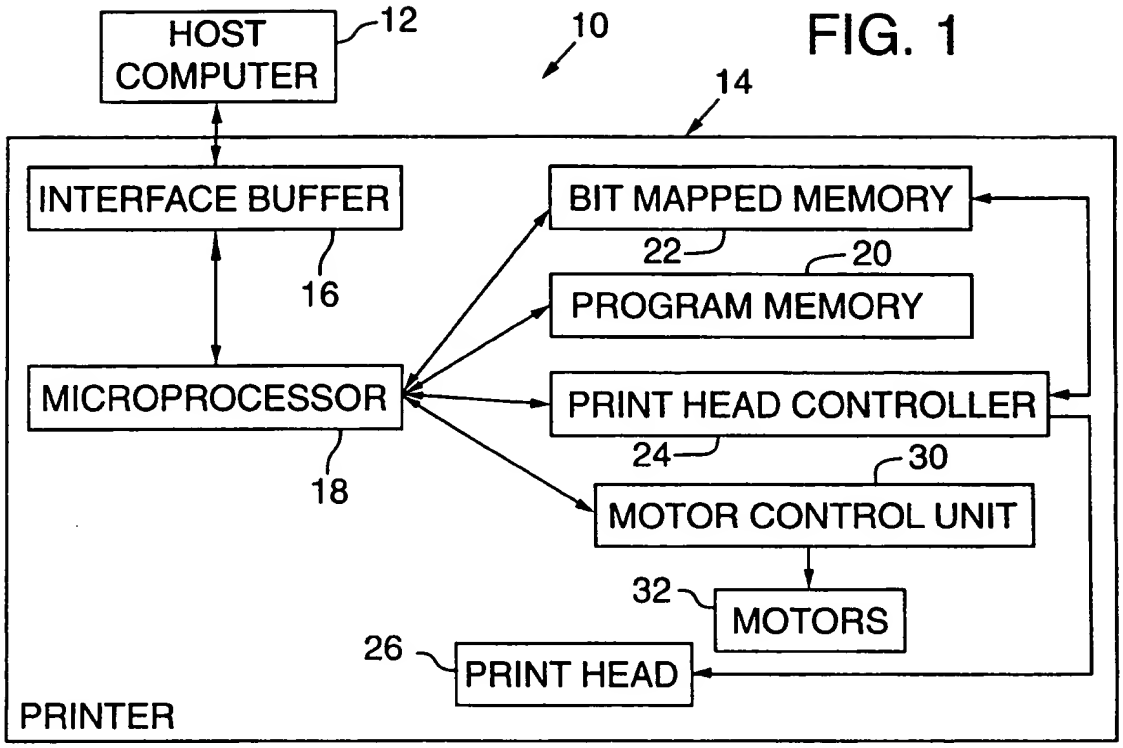

FIG. 1

FIG. 2

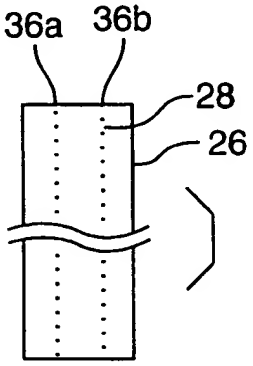

FIG. 7

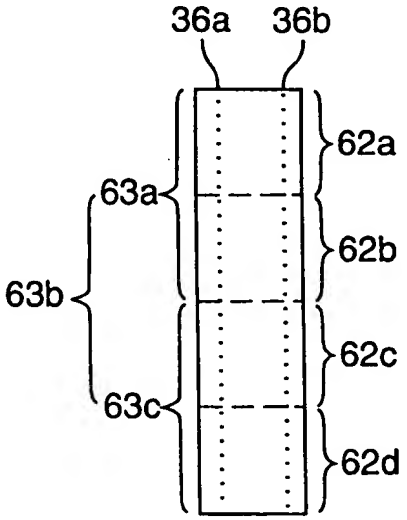

FIG. 3

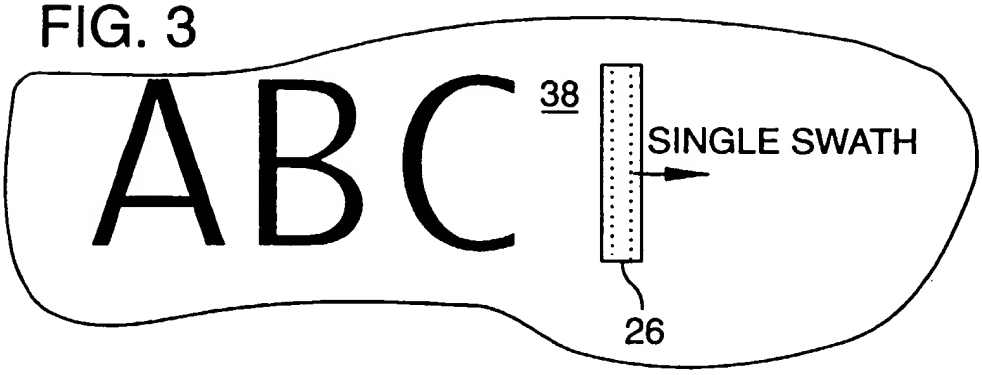

FIG. 4

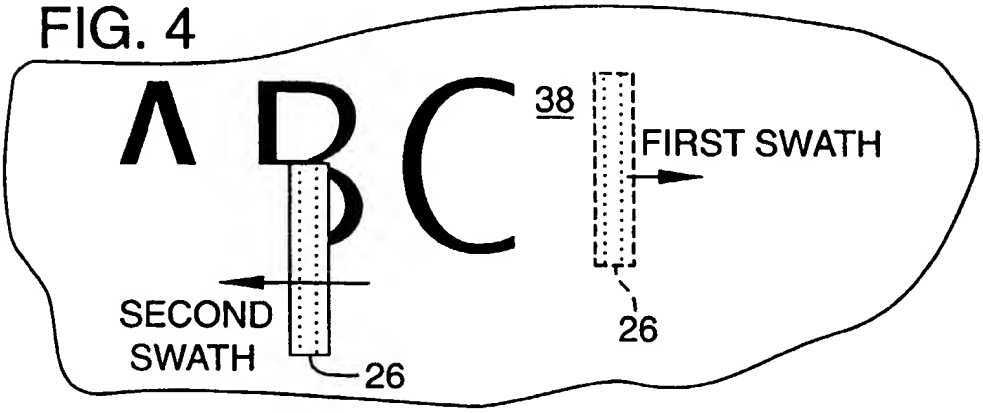

FIG. 6

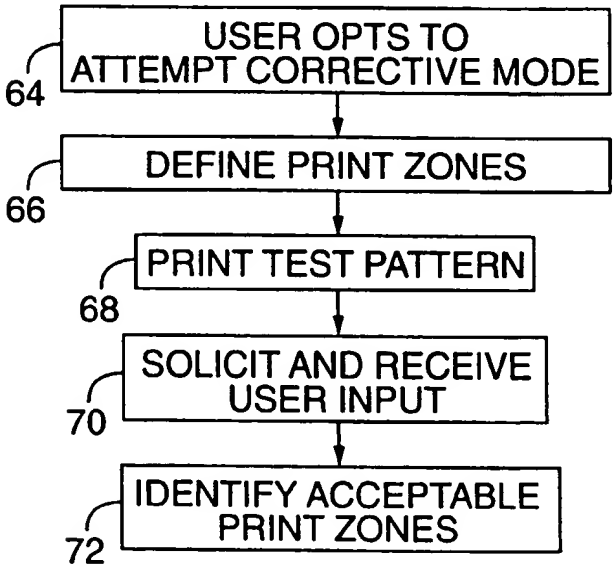

FIG. 5

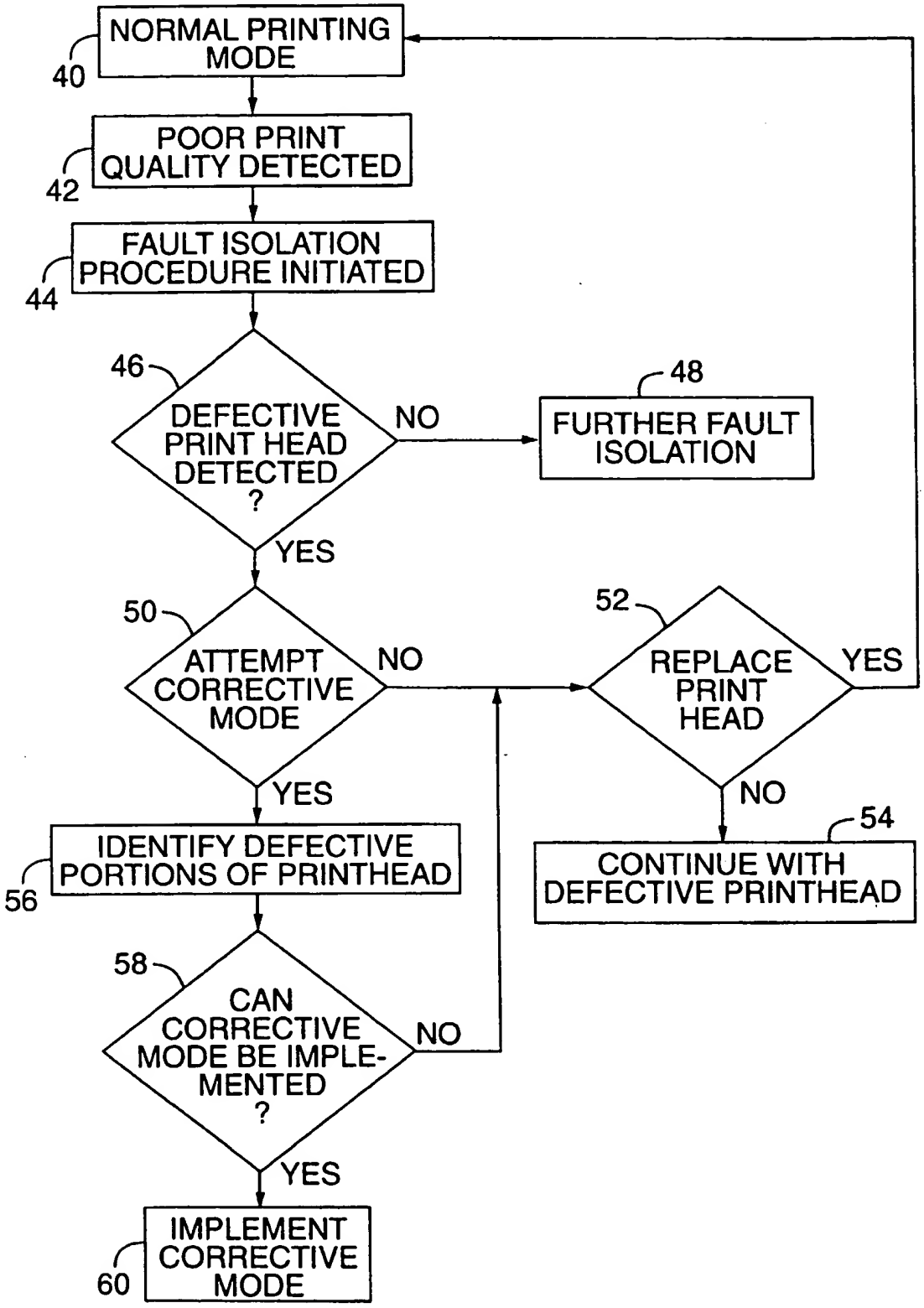
NORMAL PRINTING MODE
40
POOR PRINT QUALITY DETECTED
42
FAULT ISOLATION PROCEDURE INITIATED
44
46
DEFECTIVE PRINT HEAD DETECTED ?
NO
48
FURTHER FAULT ISOLATION
YES
50
ATTEMPT CORRECTIVE MODE
NO
52
REPLACE PRINT HEAD
YES
YES
NO
54
CONTINUE WITH DEFECTIVE PRINTHEAD
IDENTIFY DEFECTIVE PORTIONS OF PRINTHEAD
56
58
CAN CORRECTIVE MODE BE IMPLE-MENTED ?
NO
YES
IMPLEMENT CORRECTIVE MODE
60

FIG. 8

FIG. 9